Status (FY2014) & Proposal (FY2015)

Fast and lightweight

EIC integrated tracking system

Barrel MicroMegas

&

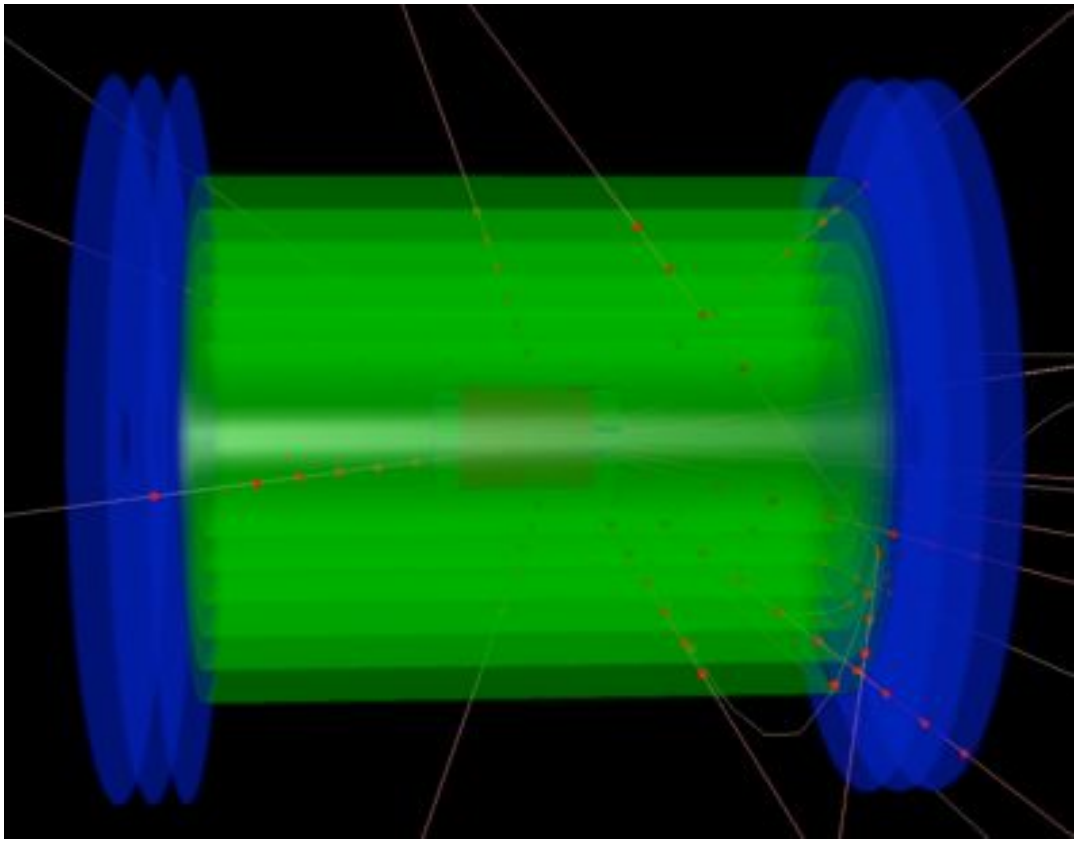
Forward Triple-GEM

Franck Sabatie (PI)

Matt Posik,
Maxence Vandenbroucke,
Bernd Surrow (PI)

Outline

- Introduction
- R&D program: Status / Proposal
  - ☆ (1) Forward GEM tracking
  - ☆ (2) Barrel MicroMegas tracking
  - ☆ (3) Front-End Readout System
  - ☆ (4) Simulations
- Budget / Schedule
- Summary



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Introduction

- Overview of RD 2012-03 effort
  - R&D effort focuses on intermediate tracking system:
    - Barrel tracking system based on MicroMegas detectors manufactured as cylindrical shell elements and
    - Rear / Forward tracking system based on triple-GEM detectors manufactured as planar segments
  - R&D effort - Main strategy:
    - Design and assembly of large cylindrical MicroMegas detector elements and planar triple-GEM detectors
    - Test and characterization of MicroMegas and triple-GEM prototype detectors
    - Design and test of new, common chip readout system employing CLAS12 'DREAM' chip development, ideally suited for micro-pattern detectors
    - Utilization of light-weight materials
    - Development and commercial fabrication of various critical detector elements
    - European/US collaborative effort on EIC detector development (CEA Saclay, and Temple University)

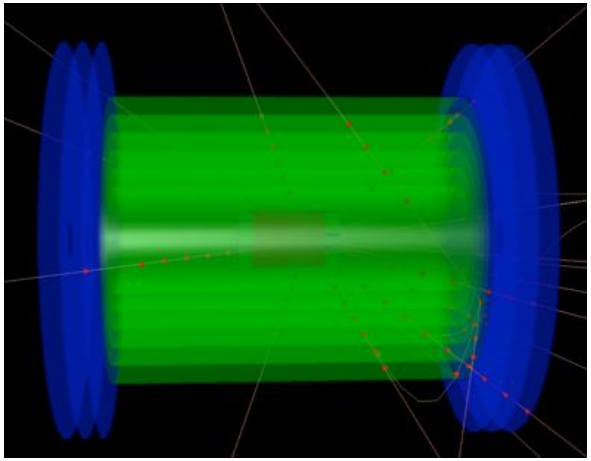
RD 2012-3

Design and assembly
of
fast and light-weight
barrel and forward tracking prototype systems
for an EIC

Progress report (Q2 FY14 / Q3 FY14) and Proposal (FY15)

S. Aune, E. Delagnes, M. Garçon, I. Mandjavidze, S. Procureur, F. Sabatié[1]
CEA Saclay

P. Bull, J. Fitzgerald, R. Harris, D. S. Gunarathne, E. Kaczanowics, A. F. Kraishan, X. Li, M. McCormick, Z. Meziani, G. Miller, D. L. Olvitt, J. Napolitano, M. Posik, B. Surrow[2], M. Vandenbroucke, J. Wilhelmi
Temple University, College of Science and Technology



Introduction

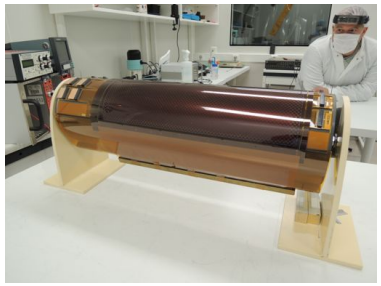
Highlights of triple-GEM R&D program

- Established reliable commercial source for single-mask produced GEM foils
- Extensive characterization of single-mask GEM foils
- Assembly of small (10 X 10 cm^2) triple-GEM test detectors and Commissioning of a new CAEN HV system for cluster studies
- Completion of all testing and tooling stations
- Procurement of polyimide spacer rings as a novel spacer grid layout / Delivery delay due to change in polyimide base material
- Completion of cosmic-ray test stand and 55Fe source scanner and Extensive utilization of DAQ / HV system
- Completion of preliminary mechanical design of a large triple-GEM detector segment
- Relocation of three labs at Temple University in September 2014 to the new Science Education and Research Center
- Hire of a new mechanical engineer (James Wilhelmi) with the hire of Professor Jim Napolitano at Temple University

Introduction

Highlights of MicroMegas R&D program / Simulations

- Design of barrel MicroMegas small radius cylindrical shells with 2D readout
- Assembly of three MicroMegas small radius cylindrical shells
- Characterization of MicroMegas detectors in cosmic-ray test stand
- Test of MicroMegas detectors using 55Fe source
- R&D of resistive technology
- Test of light-weight, low capacitance flex cables
- Test of DREAM chip production versions
- Test of DREAM-chip based DAQ system
- GEANT simulations of barrel and forward tracking detector setup
- DVCS physics simulations within EICROOT



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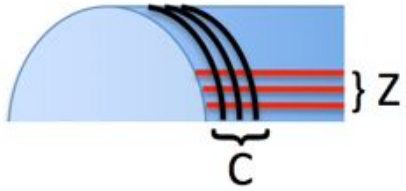

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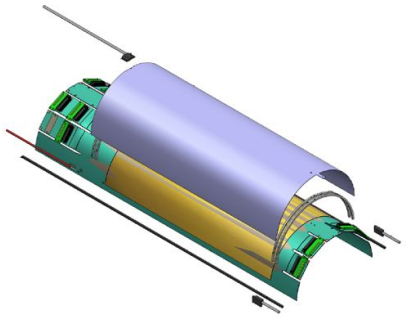

(c)

(d)

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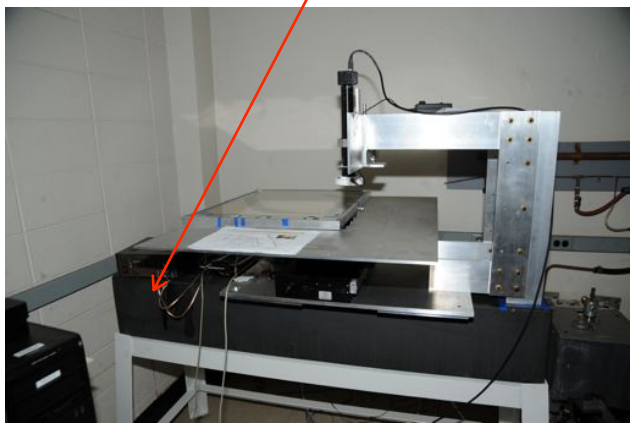
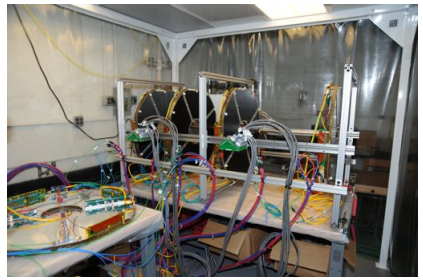
Status - Forward GEM Tracking

- Laboratory facilities at Temple University (Current Department of Physics)
  - Setup of three labs completed concerning CCD scans, assembly and testing
  - Characterization of GEM foils in terms of leakage current and optical uniformity routinely performed
  - Assembly of triple-GEM test detectors
  - Setup of cosmic-ray test and 55Fe source scanner
  - DAQ and HV system
  - Mechanical design studies on large triple-GEM detector segment (SolidWorks)
  - Commercialization of large GEM foil production using single-mask manufacturing techniques

Marble table (60" X 19" X 9 1/4") incl. stand provided by Temple University, CST

(a)





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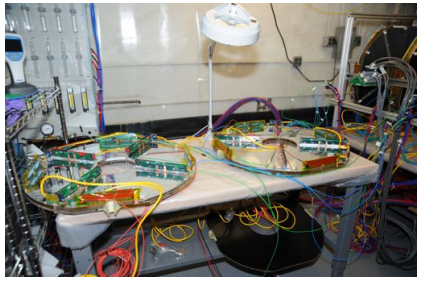

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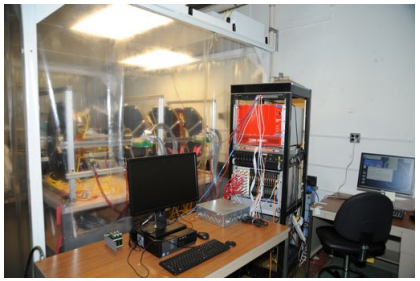

(e)

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Status - Forward GEM Tracking

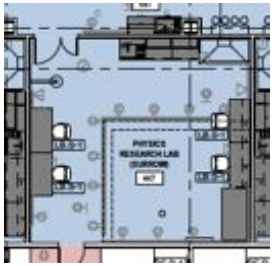
- New Laboratory facilities at Temple University (New Department of Physics)

Note: N_2, $ArCO_2$, compressed air gas lines, marble tables, furniture, fume hood, electronic racks, cable trays and clean room maintenance for Micro-pattern R&D work provided by Temple University, CST

(a)

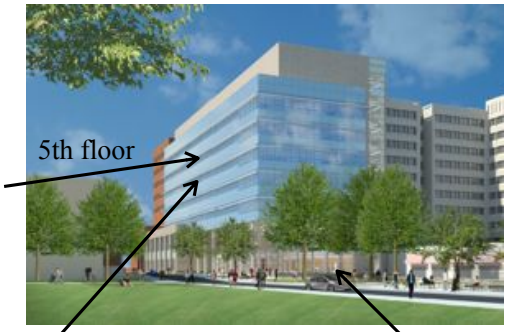
Class 1,000 Clean Room
GEM Assembly Lab

(b)



GEM testing lab

(d) Science Education and Research Center

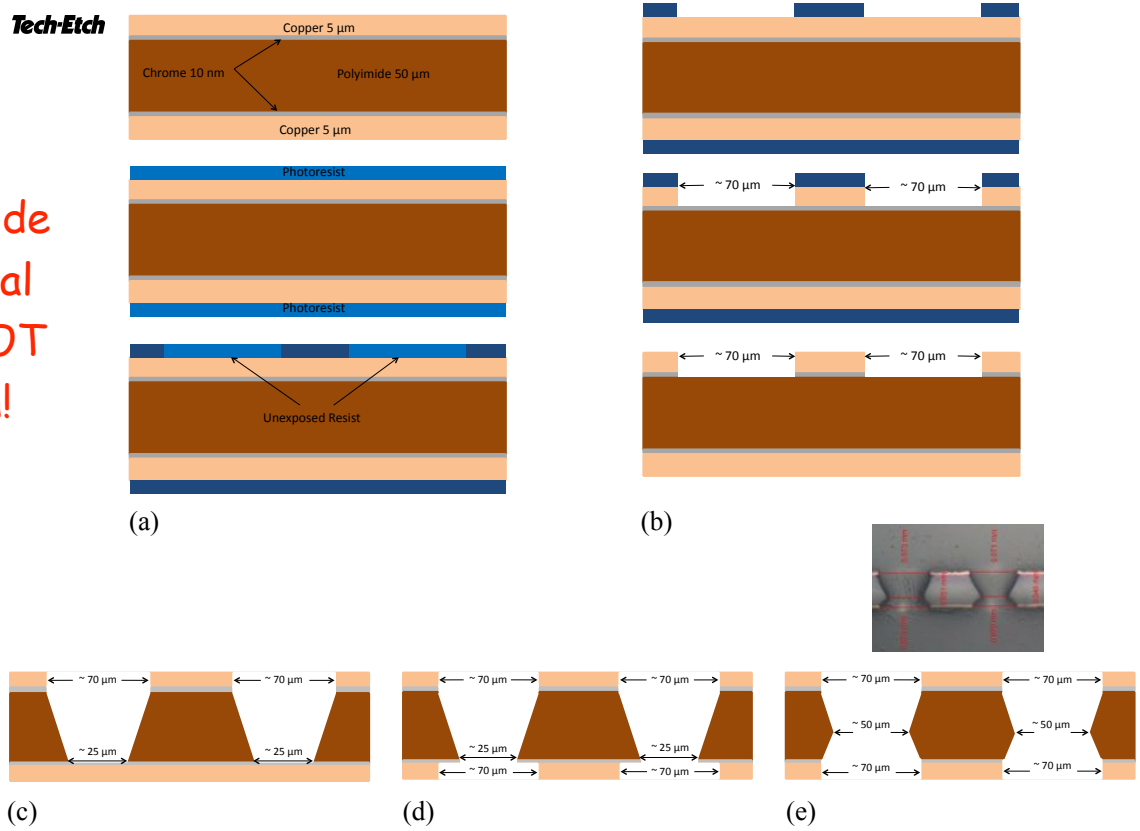


(c) Basement - Machine Shop

Status - Forward GEM Tracking

- Highlight: Commercial fabrication of single-mask produced GEM foils
  - Successful fabrication of single-mask produced GEM foils at Tech-Etch Inc. in collaboration with Temple University & Yale University
  - Processing steps:

Note: Polyimide is Apical and NOT Kapton!



(a) Coating of photoresist and laser direct imaging

(b) Removal of unexposed photoresist and etching of copper and removal of Chrome adhesive layer

(c) 1st polyimide etching in EDA chemistry

(d) Electrolyte etching and removal of backside copper

(e) 2nd polyimide etching in EDA chemistry

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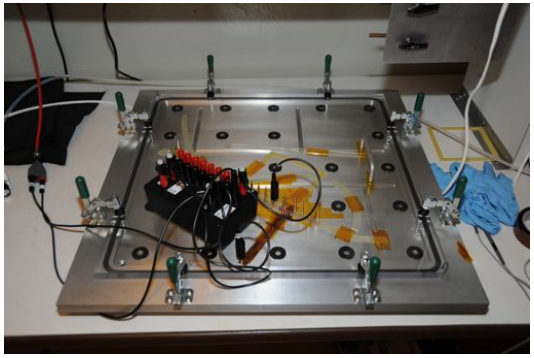
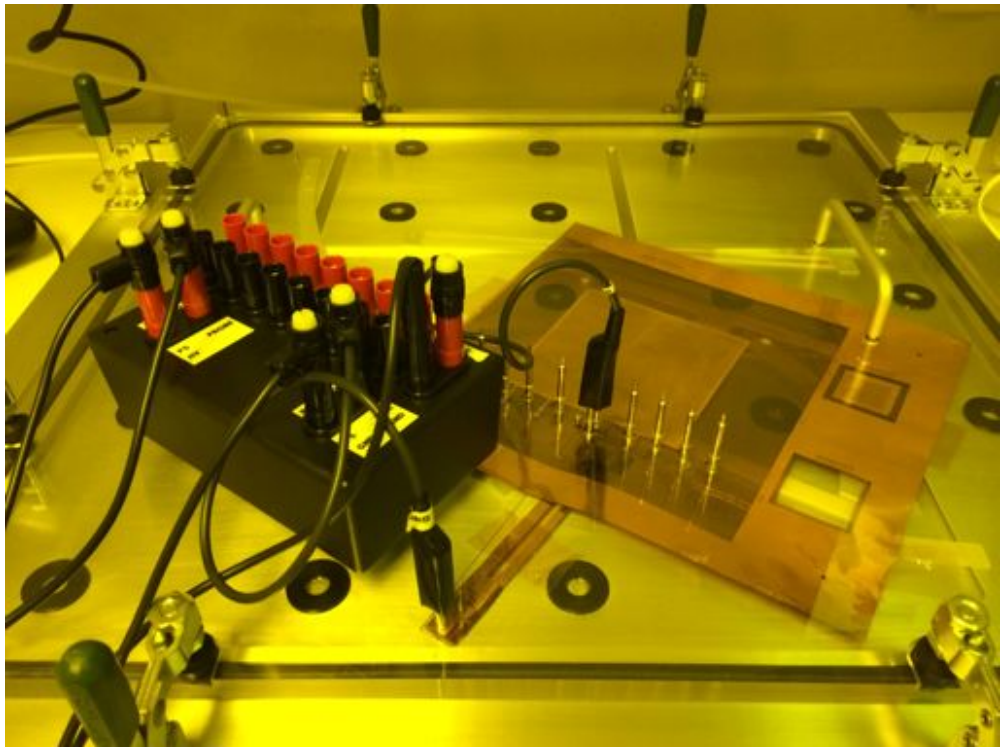
Status - Forward GEM Tracking

- Single mask GEM Foil: Electrical tests at Temple University / Leakage current (1)
  - Setup of leakage current measurement at Temple University





- Setup including nitrogen box with HV connections
- Power supply and nA current measurement

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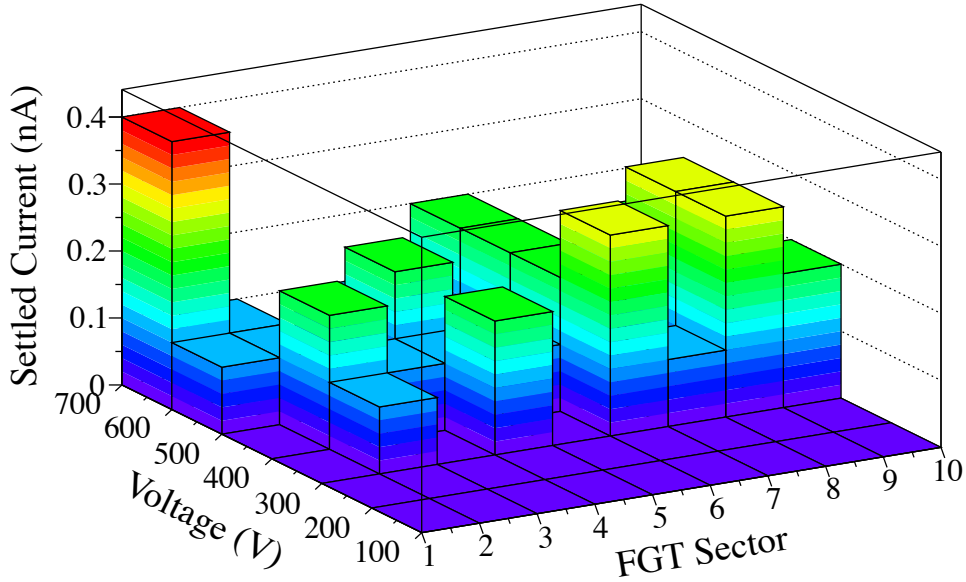
Status - Forward GEM Tracking

- Single mask GEM Foil: Electrical tests at Temple University / Leakage current (2)
  - Results for small GEM foils (10 X 10cm^2)

    Three manufacturing lots of 6 / 12 / 6 foils each were obtained which ALL showed consistent behavior, i.e. < 1nA for 0…600V

    Tech-Etch independently measured leakage current prior to packaging and shipment with same results!
  - Results for large GEM foils (40 X 40cm^2)



  - Very small currents < 1nA repeatedly measured for 3 large GEM foils (40 X 40cm^2)
  - **Critical step**: Switch from Kapton polyimide base material to Apical base material as suggested by CERN / Previous base material by Tech-Etch was Kapton with typically X 10 larger leakage current

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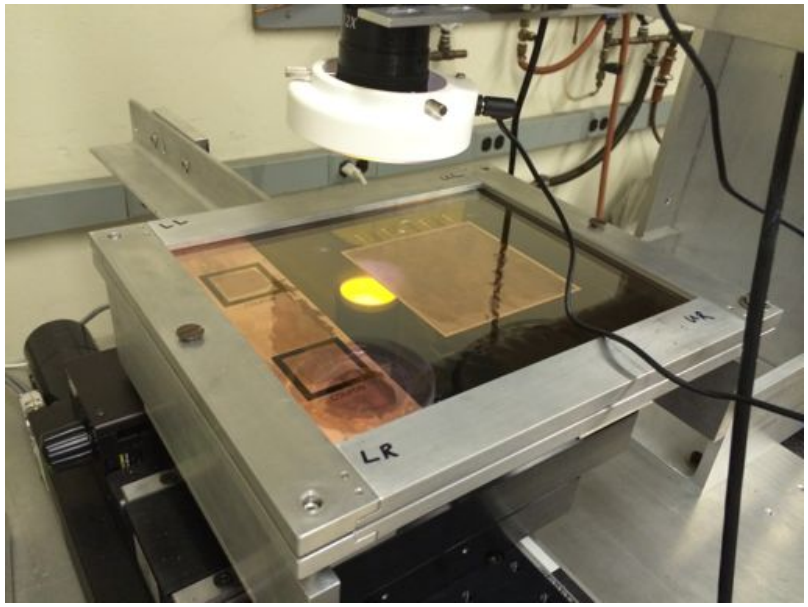
Status - Forward GEM Tracking

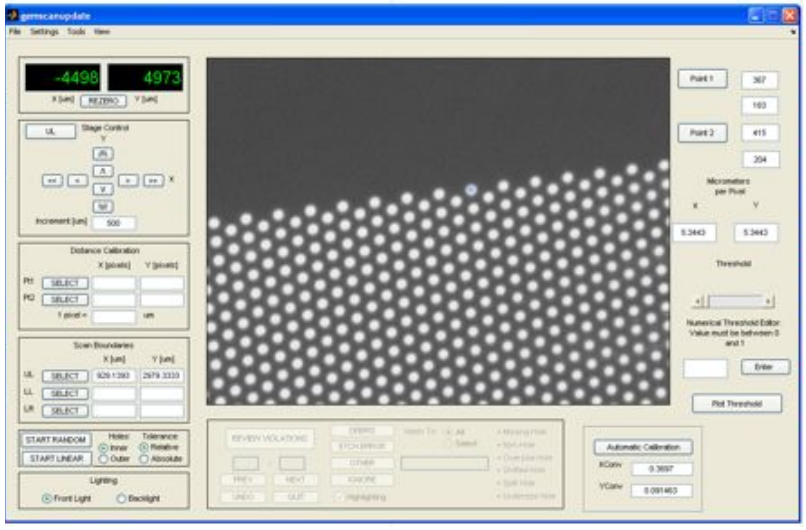
- Single mask GEM Foil:

  CCD scan setup

  - 2D scanning table with CCD camera fully automated
  - Scan GEM foils to measure hole diameter (inner and outer) and pitch
  - Unique world-wide setup in micro-pattern detector community
  - Critical for feedback in development and QA stage!



(a)



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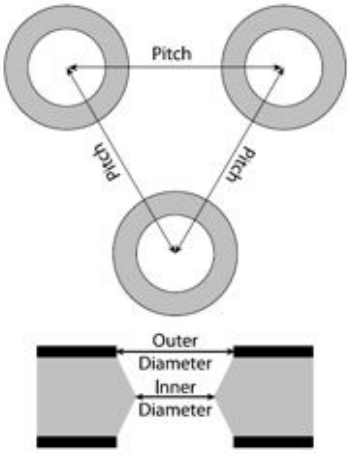

(c)

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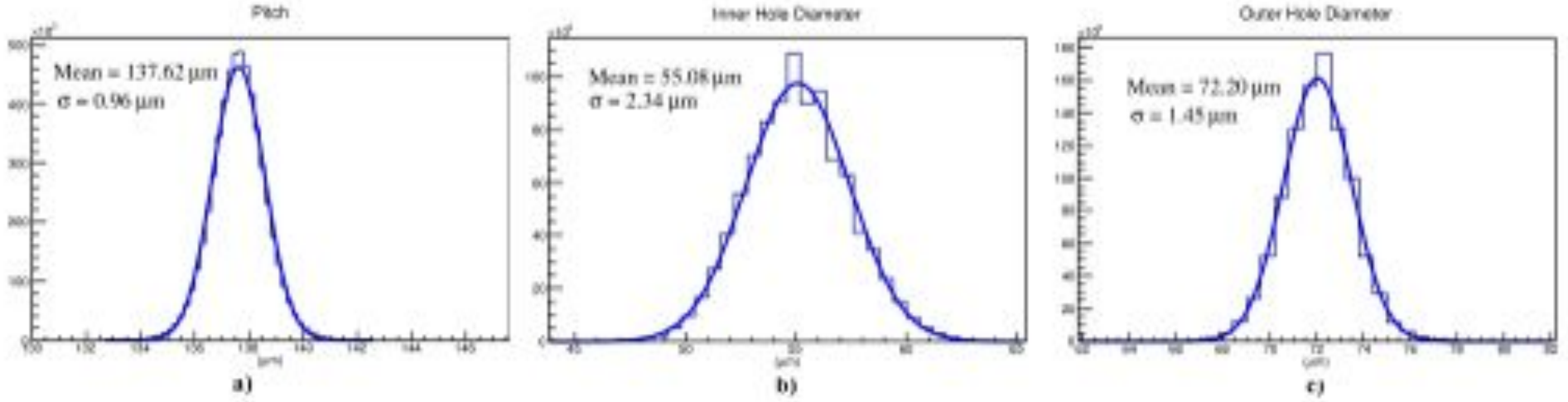
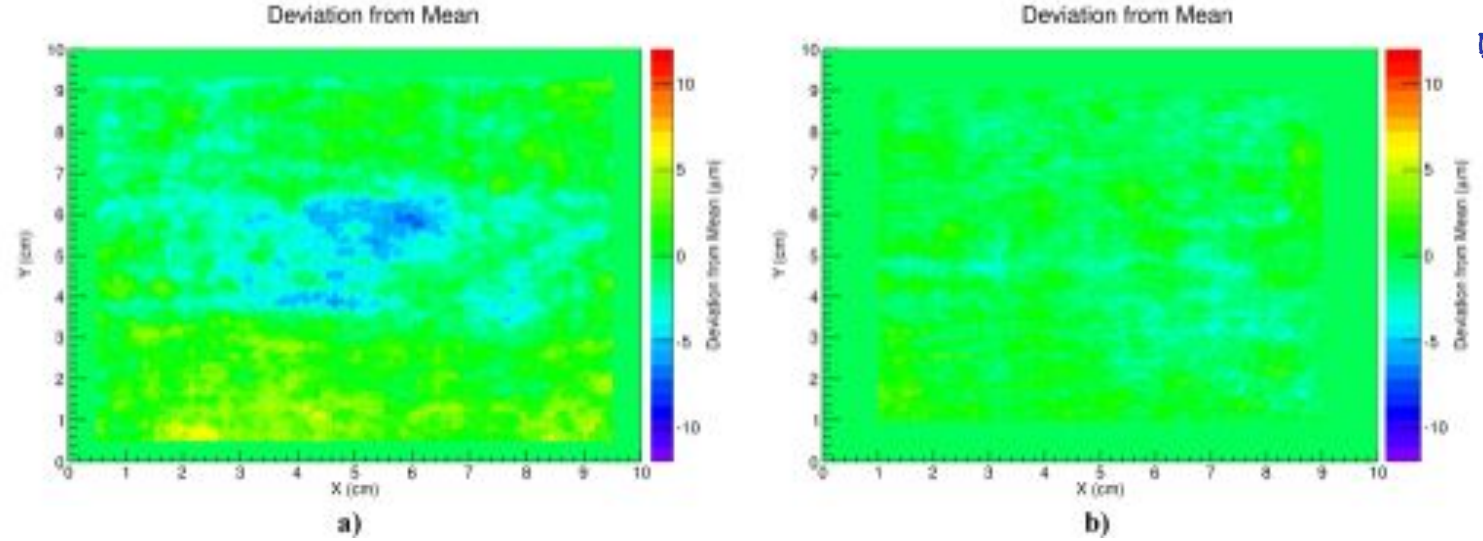
Status - Forward GEM Tracking

- Single mask GEM Foil: CCD scan results / Small samples (1)





- Simple model calculation yields a completely negligible effect of the established σ (Inner Hole diameter) on the reconstructed hit position and resolution

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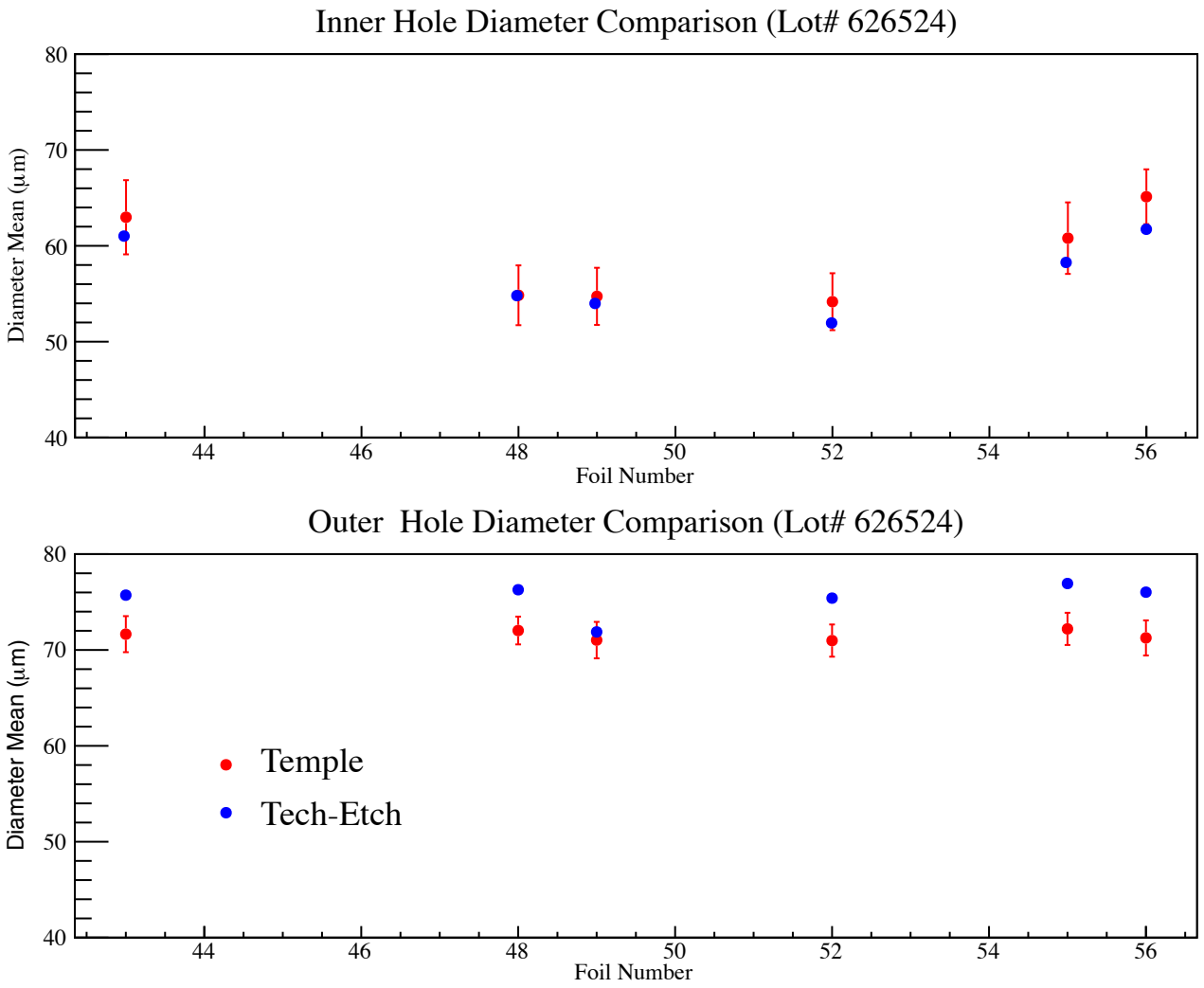
Status - Forward GEM Tracking

- Single mask GEM Foil: GEM Foil CCD scan results / Small samples (2)



- Feedback from optical and electrical measurements at Temple University during development steps absolutely critical for Tech-Etch
- Tech-Etch has established strict handling and QA procedures based on numerous discussions and site visits

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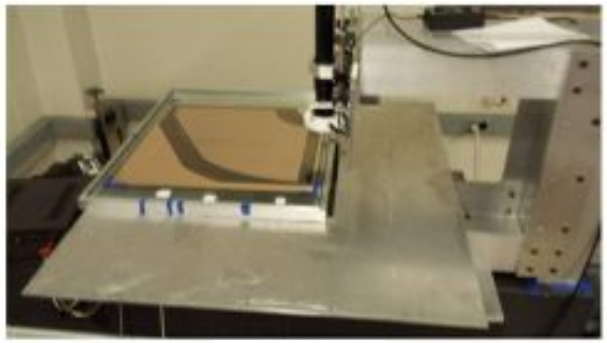
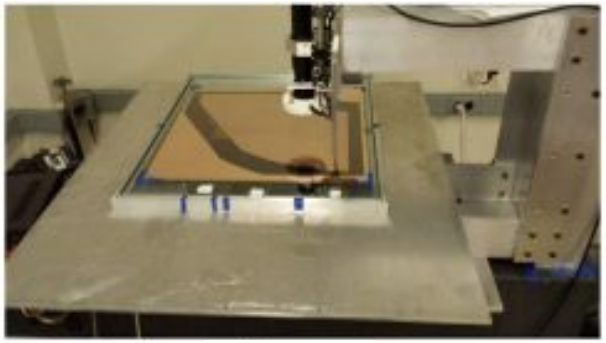
Status - Forward GEM Tracking

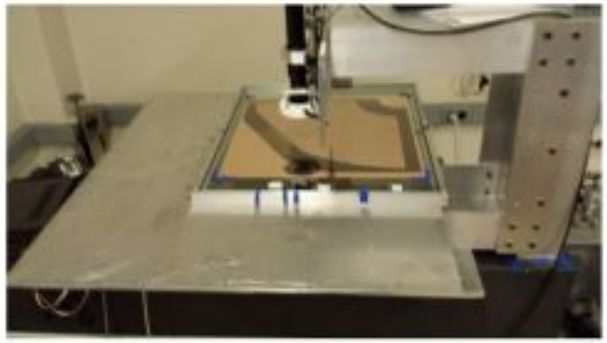
- Single mask GEM Foil: CCD scan results / Large samples (1)



Setup A

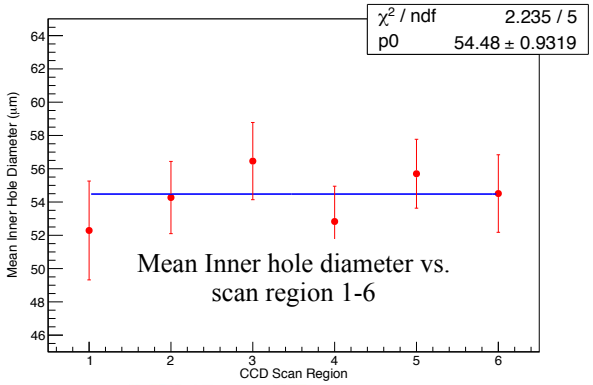


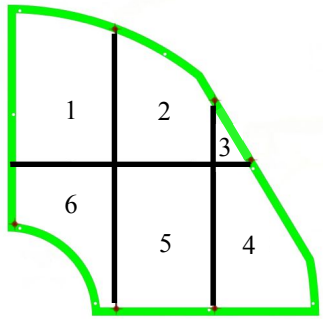
Setup B

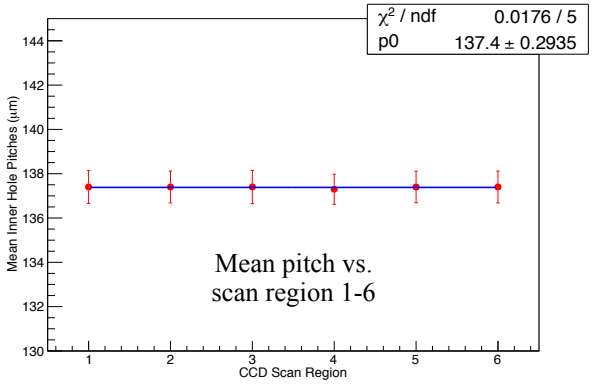


Setup C

- Consistent inner hole diameter of ~55µm for all 6 regions identical to small GEM foils
- Completely flat pitch for all six regions close to ~140µm
- Small X/Y travel of CCD scanner results in very long total scanning time ➜ Upgrade for large foils urgently needed!







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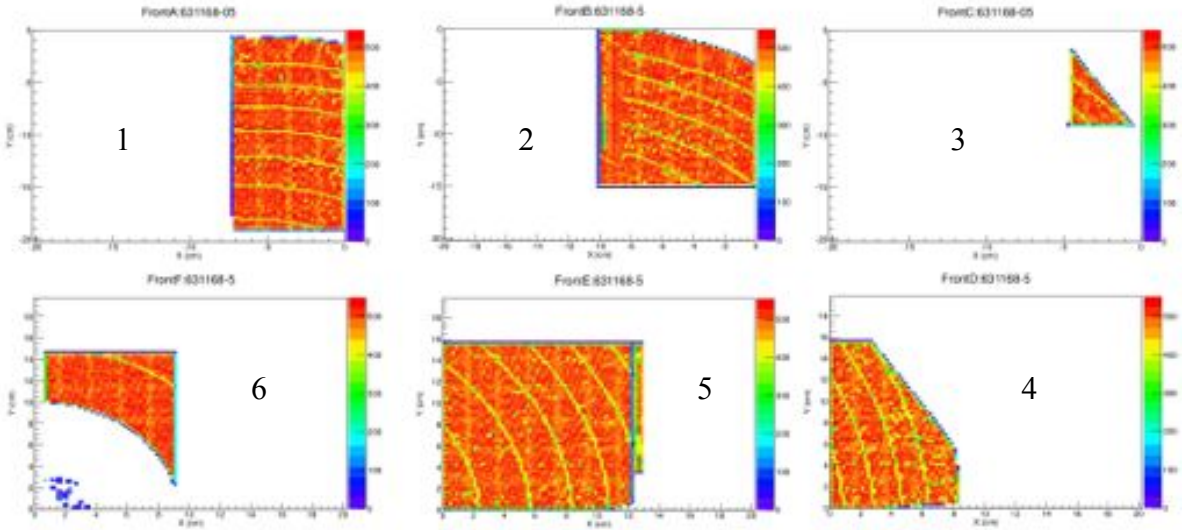
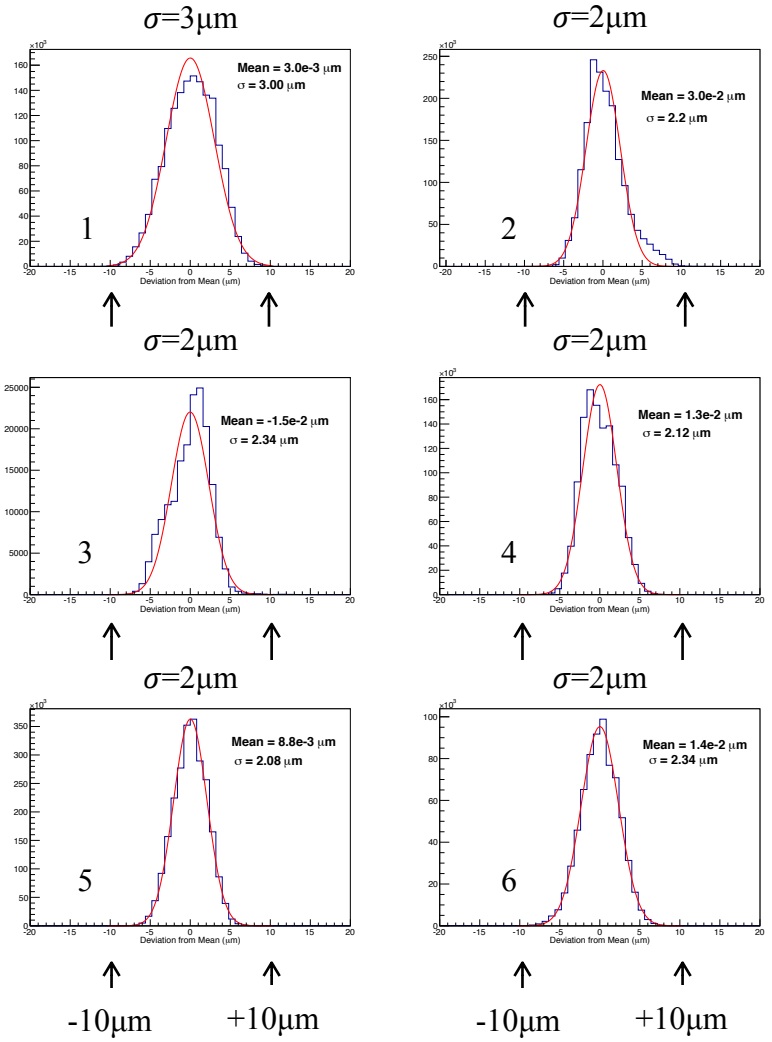
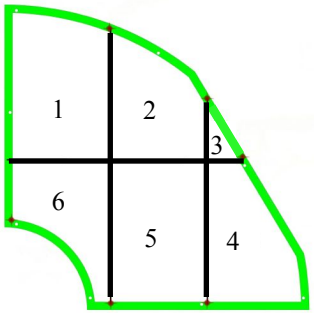
Status - Forward GEM Tracking

- Single mask GEM Foil: CCD scan results / Large samples (2)





- Measurement yield of CCD images for each of the 6 regions
- Boundaries and GEM foil segmentation boundaries are clearly visible



- Simple model calculation yields a completely negligible effect of the established σ (Inner Hole diameter) on the reconstructed hit position and resolution

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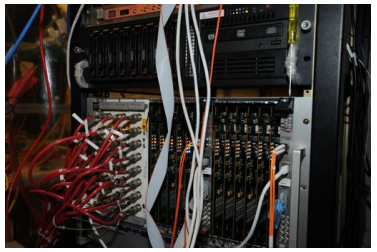
Status - Forward GEM Tracking

Status - Forward GEM Tracking (1)

- Complete FEE (APV25-S1) / DAQ system operational
- Spacer ring material changed from Kapton to Apical / Delivery expected late summer 2014
- Preliminary GEM foil design finalized / Preparation of Gerber file started

(a)



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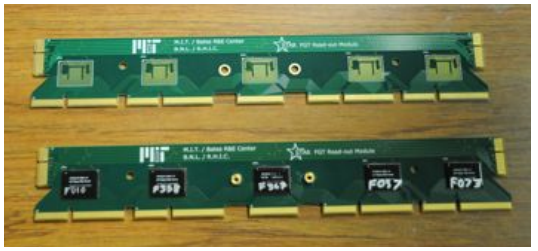

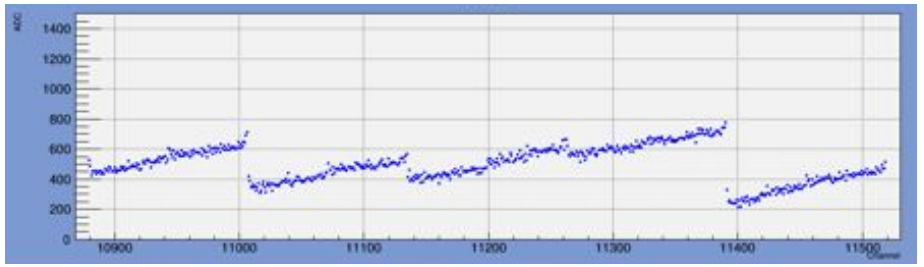

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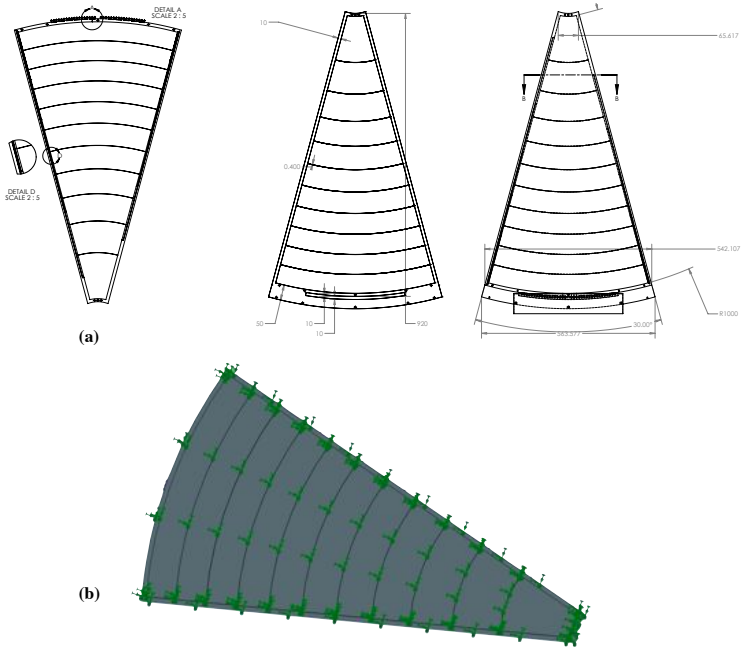

(a)

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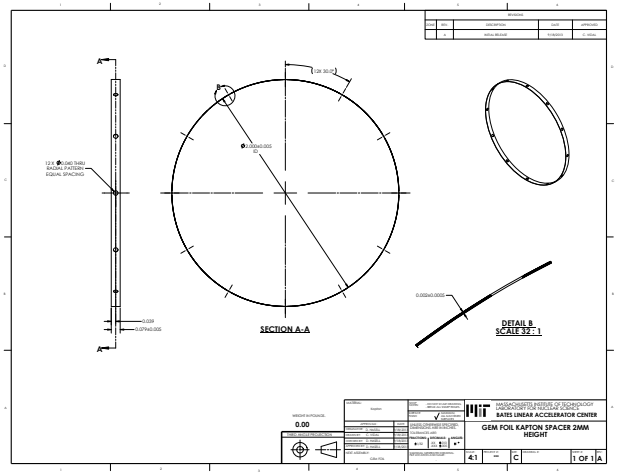

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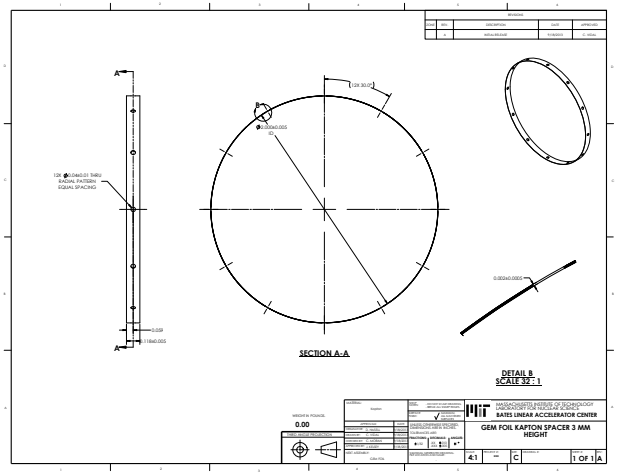

(b)

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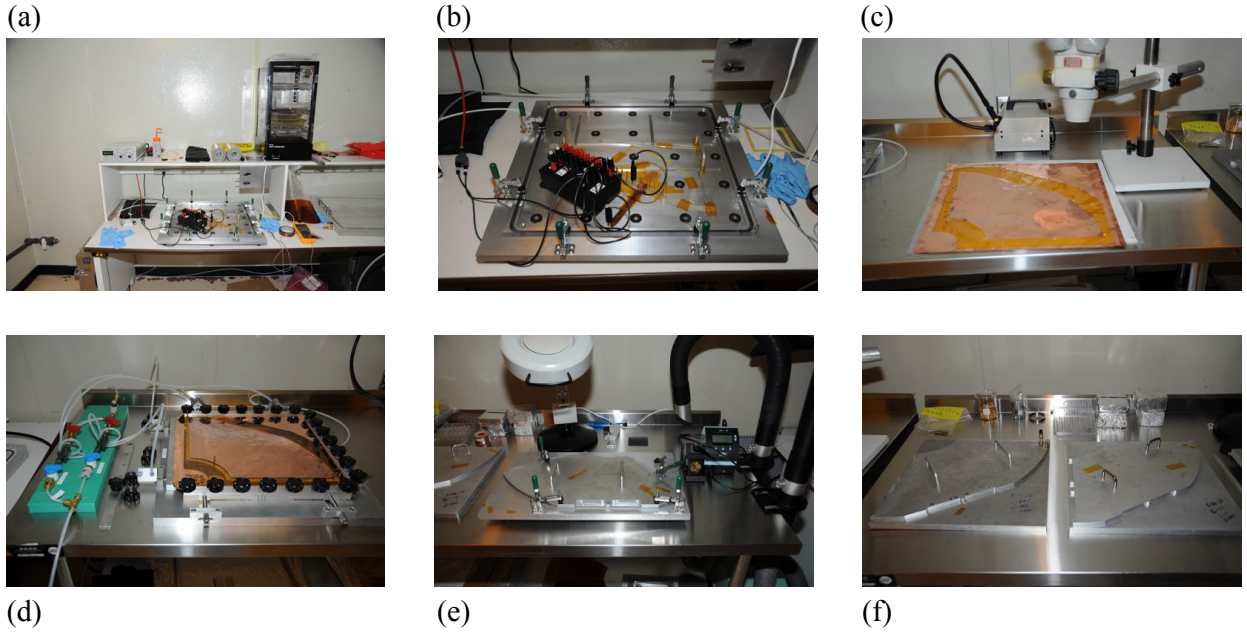
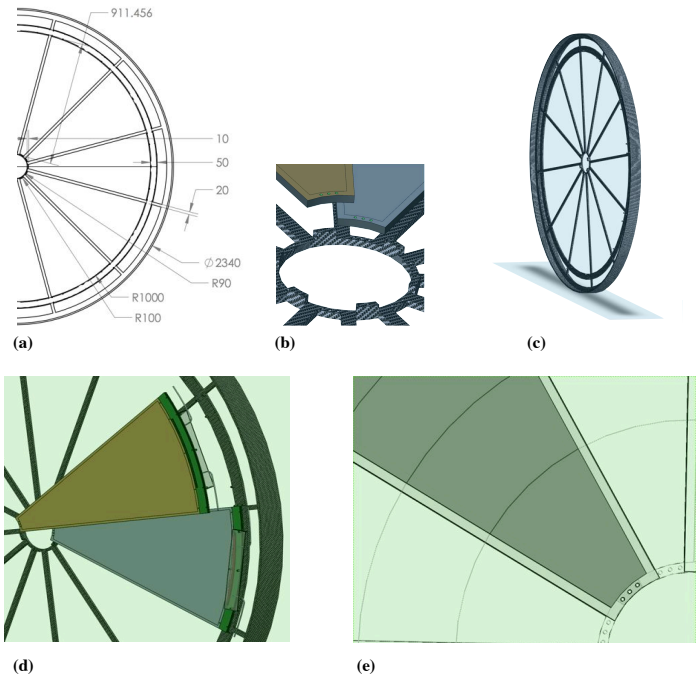
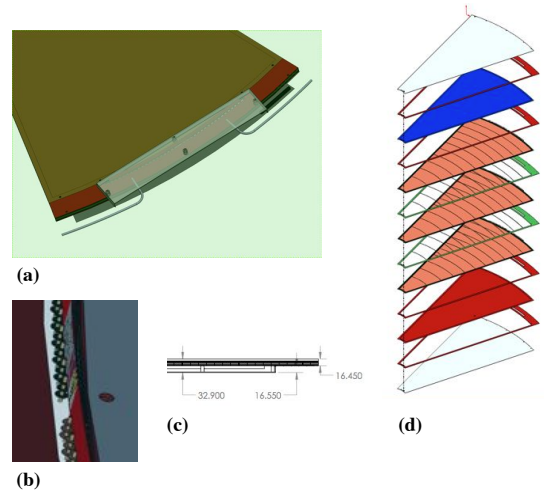
Status - Forward GEM Tracking

Status - Forward GEM Tracking (2)







- All testing and assembly tools commissioned and operational
- Preliminary design of large EIC specific triple-GEM segment and support structure finalized

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Proposal - Forward GEM Tracking

Proposal (1)

- Characterization of single-mask GEM foils from CERN in collaboration with R. de Oliveira / Expect samples by August 2014

- Characterization of large single-mask GEM foils of 50 X 50cm^2 / ALICE R&D program in collaboration with YALE University
- NIM paper in preparation on commercial fabrication up to 50 X 50cm^2
- Presentation of recent work at recent RD51 collaboration meeting and upcoming IEEE 2014 conference
- Urgently needed: Upgrade of CCD scanner at Temple University to accommodate large GEM foils / Setup also needed for large area 55Fe scans similar to existing setup for 40 X 40cm^2 sectors
- Assembly and test of 40 X 40cm^2 sectors with spacer rings using Apical rings and single-mask GEM foils

New large CCD scanning setup: Linear motor stage and controller mounted on Marble table provided by TU, CST with bottom, large area light and CCD camera

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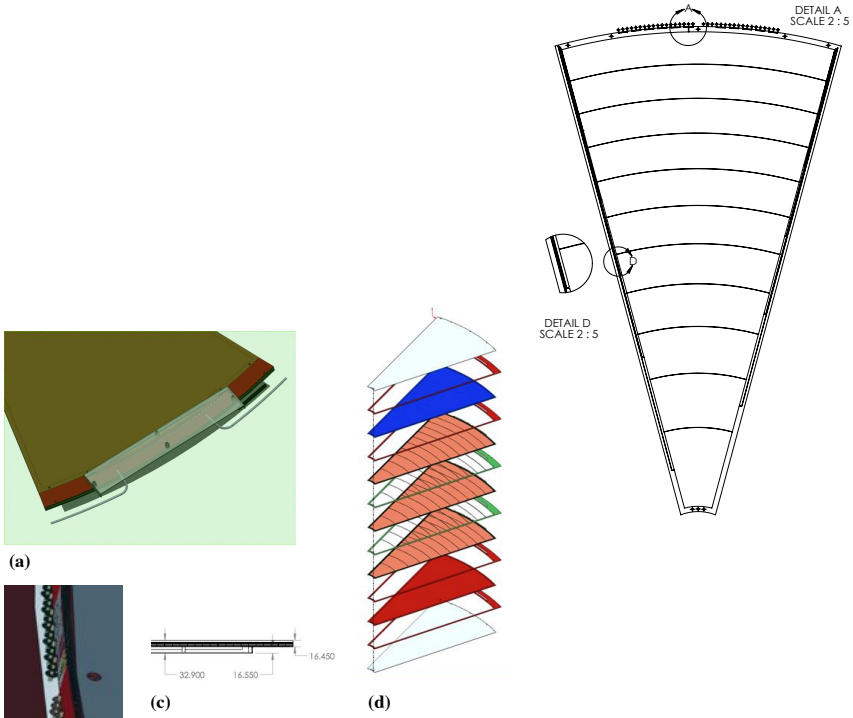
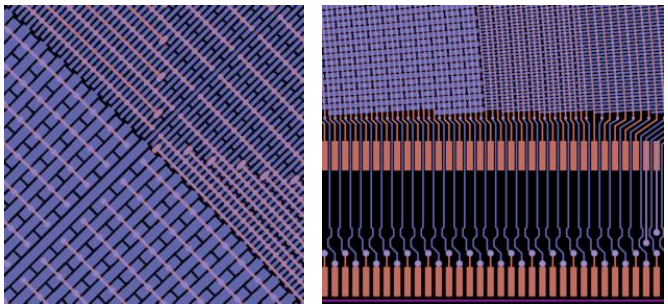
Proposal - Forward GEM Tracking

- Proposal (2)
  - Finalize design of large, **dedicated EIC triple-GEM segment** of ~50 X 120cm^2 in collaboration with Florida Institute of Technology and University of Virginia
  - Commercial production of very large GEM foils and 2D readout foils of ~50 X 120cm^2
    - Bi-weekly coordination meetings with Tech-Etch Inc. incl. CERN (GEM foils / 2D readout foils / New: Start MicroMegas discussion)
    - Feedback on optical scans and electrical performance to Tech-Etch critical
    - Last step profiting from EIC R&D program ➜ Enormous benefit to wider nuclear and particle physics community!



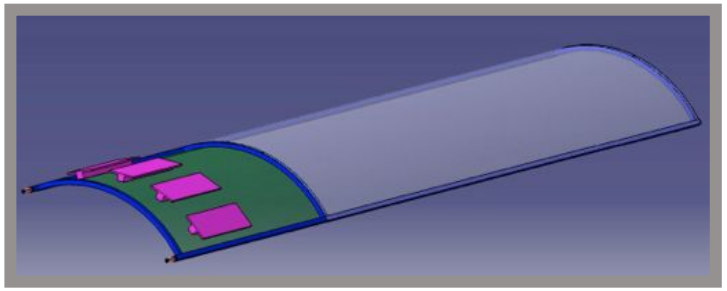


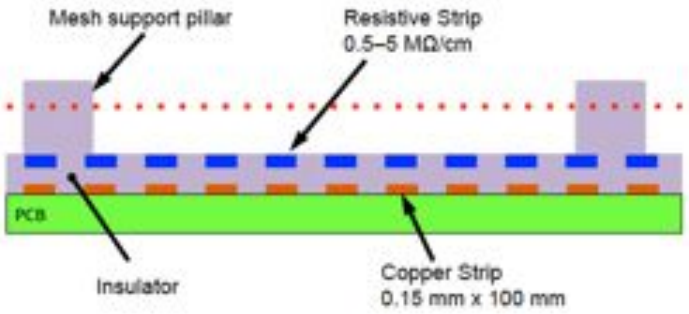
Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

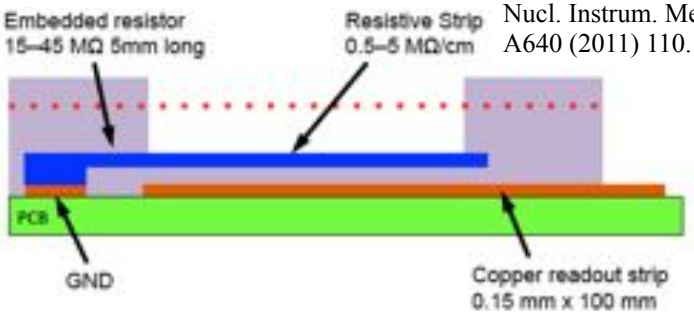
Status - Barrel MicroMegas tracking

Introduction

- Curved MicroMegas for barrel based on carbon structure glued on thin PCB
- Idea validated for CLAS12 tracker
- Need to increase size: PCB size, mesh tension, capacitance and gain homogeneity
- Transition to resistive technology for MicroMegas detectors / No measurable sparking





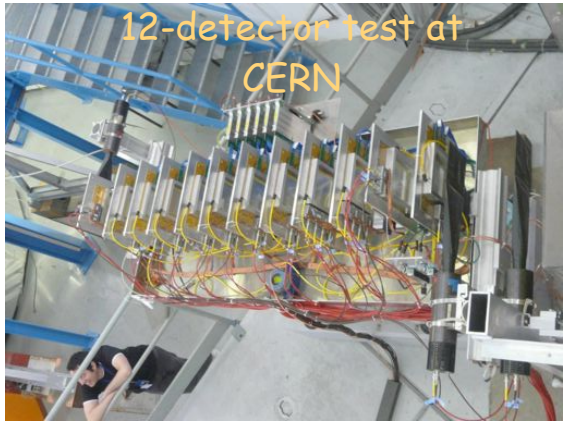


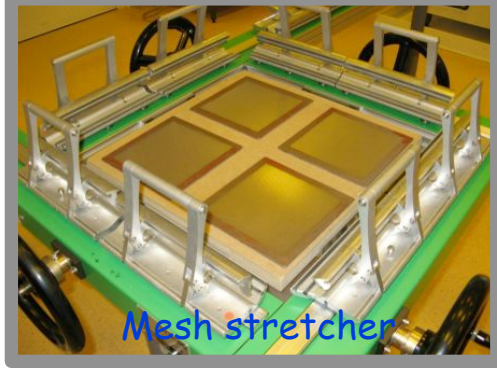
T. Alexopoulos et al., Nucl. Instrum. Meth. A640 (2011) 110.

Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

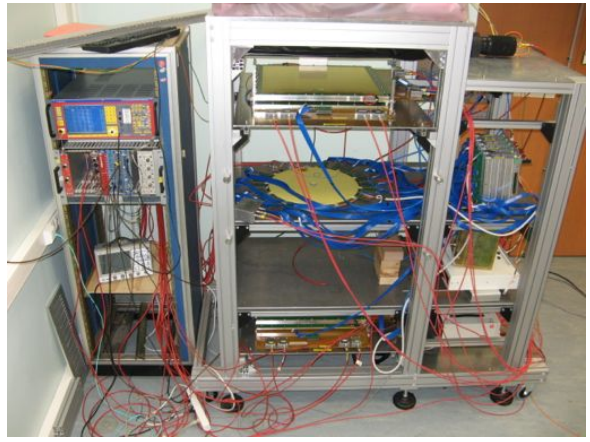
Status - Barrel MicroMegas tracking

- Laboratory facilities at Saclay





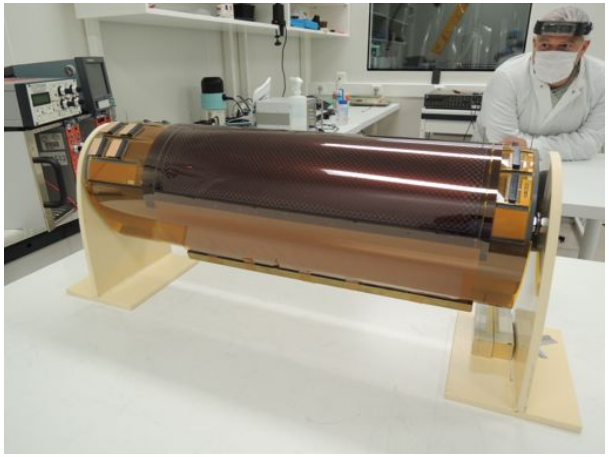
- MicroMegas detectors build either at outside company (CIREA/ELVIA) or at Saclay workshop
- Tests done in CLAS12 lab with fully-equipped cosmic-test stand incl. reference detector



Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

Status - Barrel MicroMegas tracking

- Highlight: Assembly and test of curved MicroMegas cylindrical segments (1)
  - Successful assembly of small radius prototype
  - Challenge: Mechanical stress due to large bending
  - 2D readout (C/Z strips) structure on thin PCB (Succeeded in challenging production involving ~100k VIA connections / holes)
  - Readout through DREAM chip system



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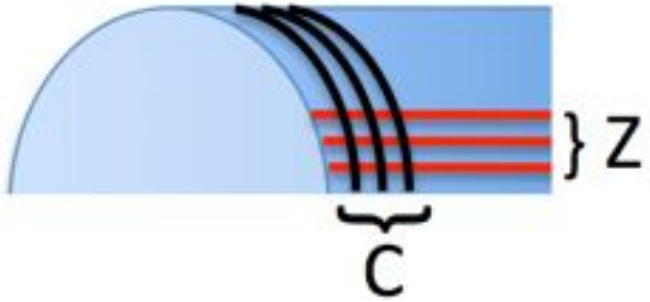
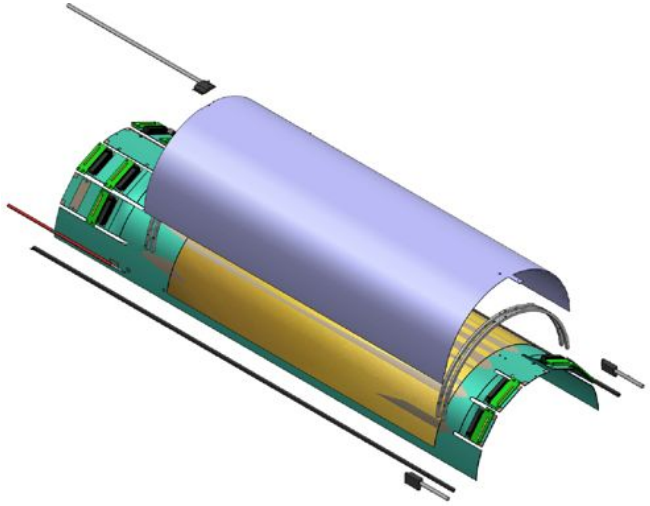


(b)



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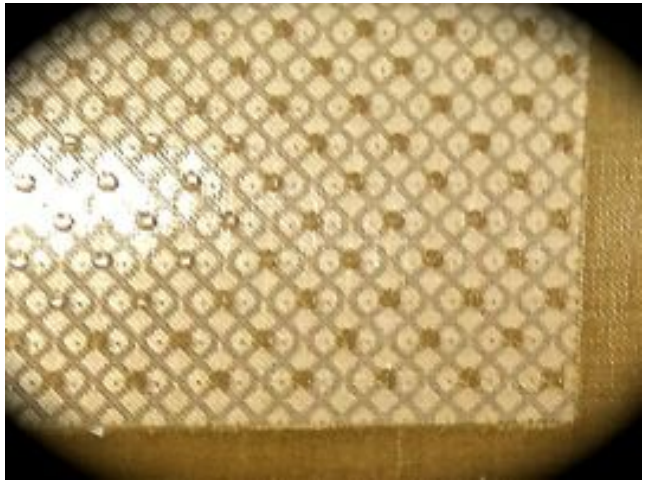

(d)

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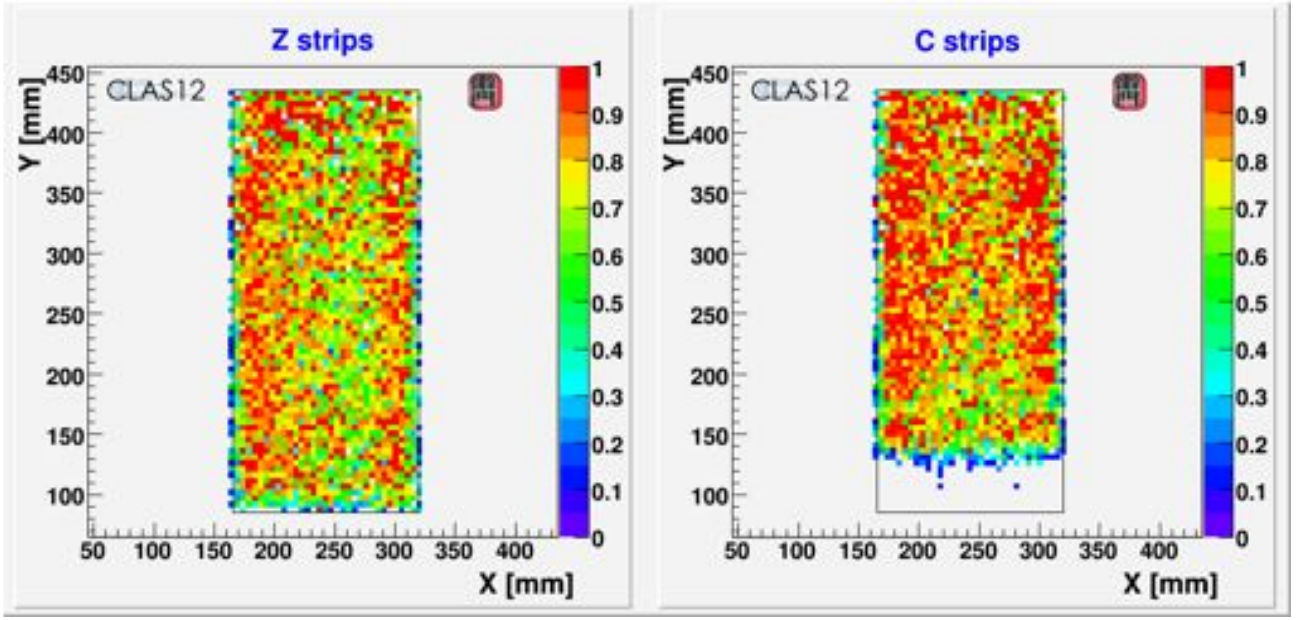
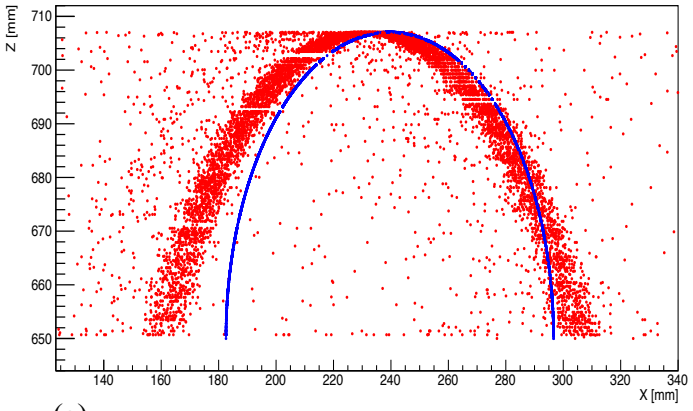
Bernd Surrow (PI) and Franck Sabatie (PI)

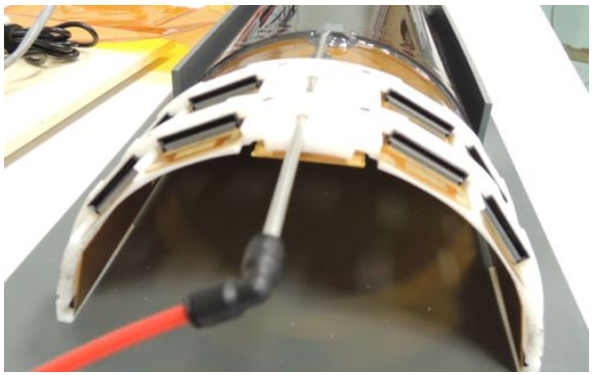
Status - Barrel MicroMegas tracking

- Highlight: Assembly and test of curved MicroMegas cylindrical segments (2)
  - Full characterization with cosmic rays for efficiency, spatial and time resolution
  - 55Fe source gain and energy resolution characterization
  - Further R&D on mechanical deformation / Mechanical structure built using 3D printing





(a)



(b)

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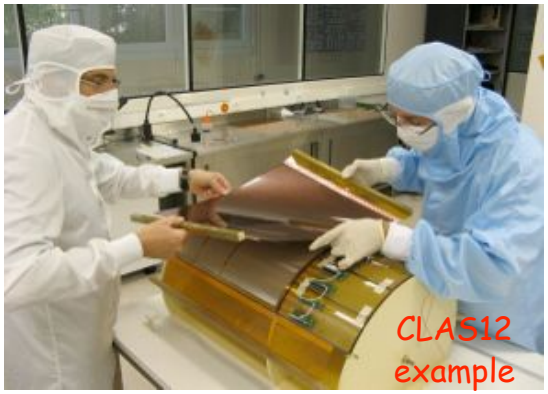
Bernd Surrow (PI) and Franck Sabatie (PI)

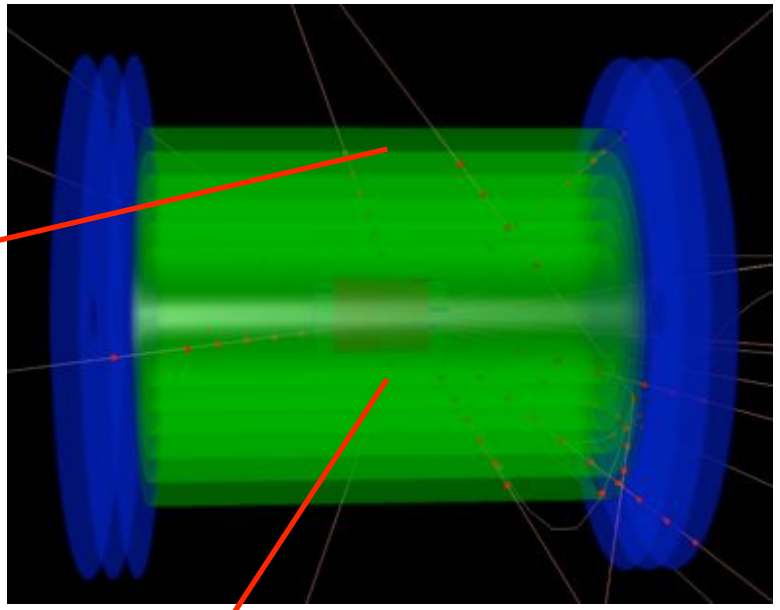
Proposal -Barrel MicroMegas tracking

Proposal - MicroMegas R&D program

- Further test of small radius MicroMegas detector
- Assembly and test of large radius Resistive MicroMegas cylindrical shell
- Design and assembly of a full scale large radius Resistive MicroMegas cylindrical shell with 2D readout
- Discussion with Tech-Etch on MM Tech. Transfer (2D / Resistive bulk) - Long-term
- In addition:
  - Optimization of material budget
  - Optimization of geometry
  - Multiplexed readout

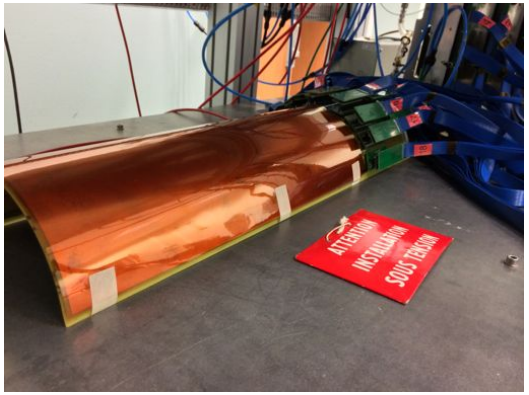


Large radius MM



Small radius MM

MM Technology transfer to Tech-Etch (US) similar to CIREA/ELVIA (EU)

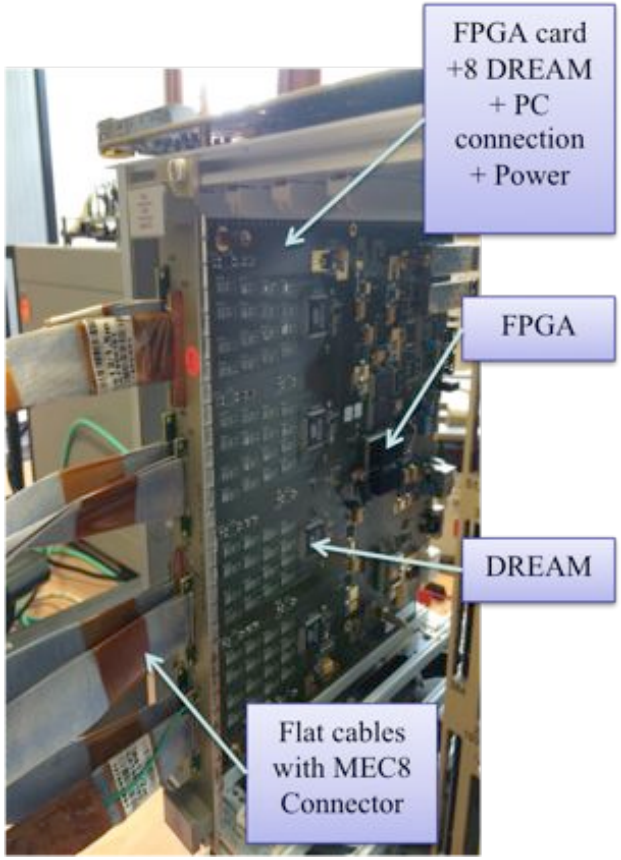


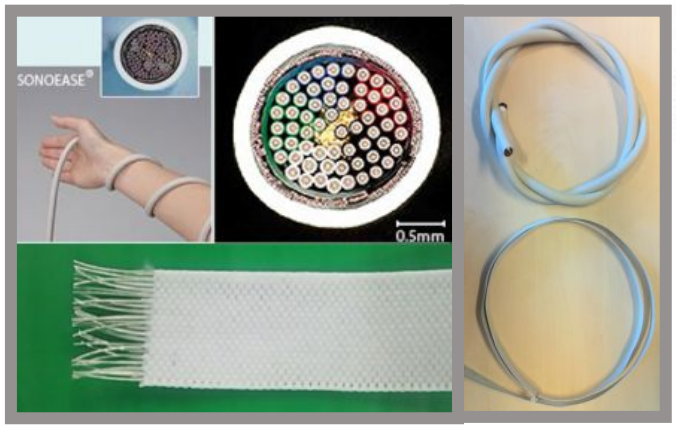
S. Procureur, R. Dupre, and S.Aune, Nucl. Instrum. Meth. A729, 888 (2013).

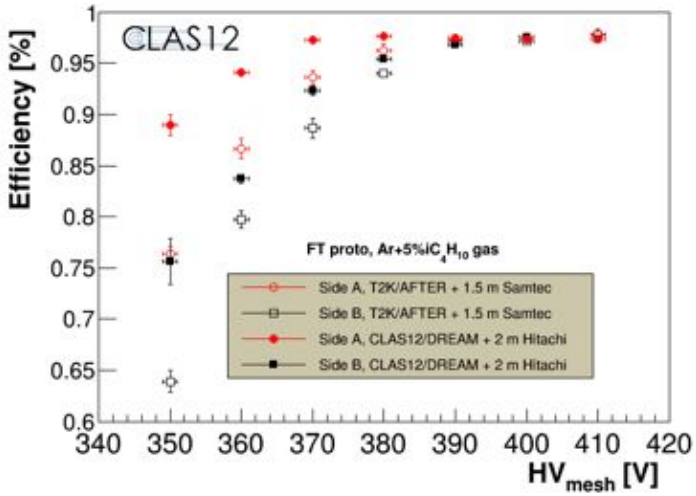
Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

Status - Front-End Readout System

- Front-End Electronics development







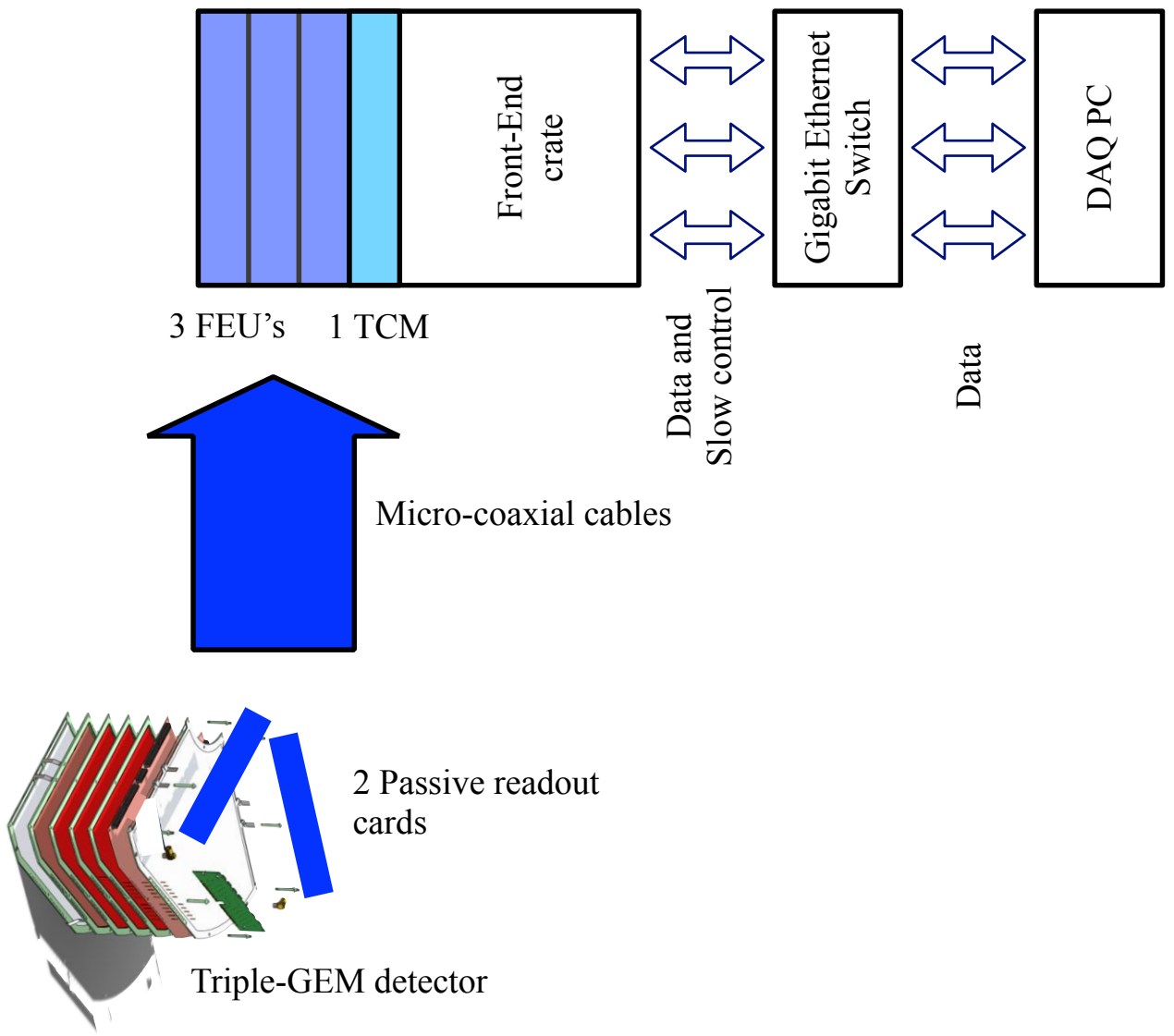
- Successful setup of complete new chip readout system ideally suited for Micropattern detectors
- Successful test with MicroMegas detector
- FEE Cards produced and tested with, and, without spark protection circuit - Noise level with 60cm long cylindrical detectors + 2m flat cables ~3000e-

	Dream Chip	APV25-S1 Chip
Number of channels	64	128
Memory size	512	160
Latency	16μs	8μs
Noise (e-RMS)	2100 (On 180pF)	1200 (On 20pF)
Sampling frequency	1-40MHz	10-50MHz
Dynamic range	50-600fC	150fC
Input capacitance	150pF	18pF
Shaping time	70ns	50ns

Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

Proposal - Front-End Readout System

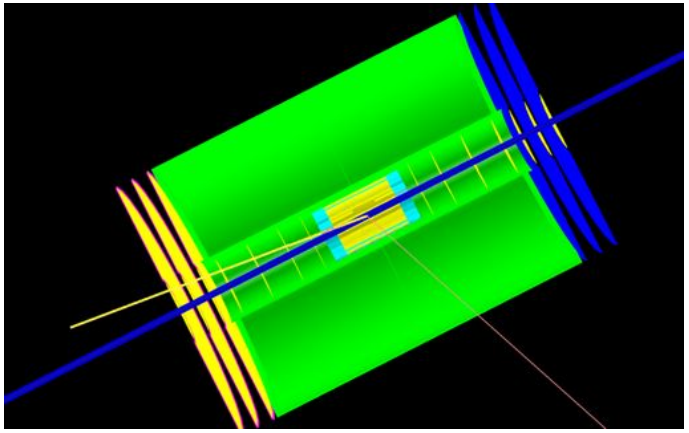
- Proposal
  - Setup of DREAM chip FEE applied to large triple-GEM detectors
  - Design / Fabrication of Very-Front-End-Board
  - Studies of packaged / bonded DREAM ASIC
  - DREAM ASIC irradiation studies
  - Evaluation of multi-VFEM system



Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

Status - Simulations

- EICROOT simulation
  - GEANT Implementation of barrel MicroMegas and rear/forward triple-GEM system
  - Resolution studies / Kinematics
  - Dead material studies
  - Installation of EICROOT on Saclay's computer grid (iclust)
  - DVCS physics simulations



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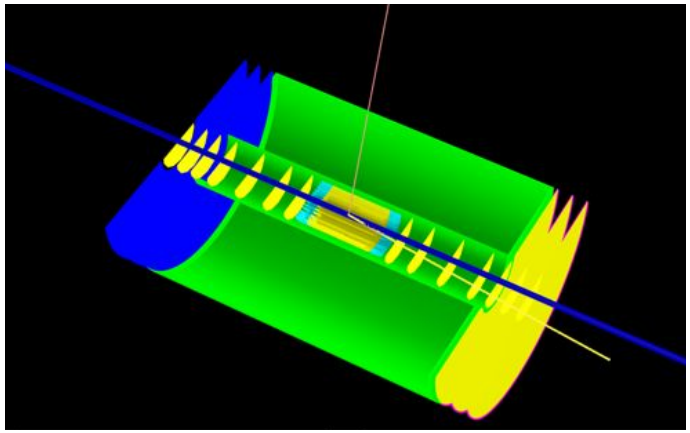
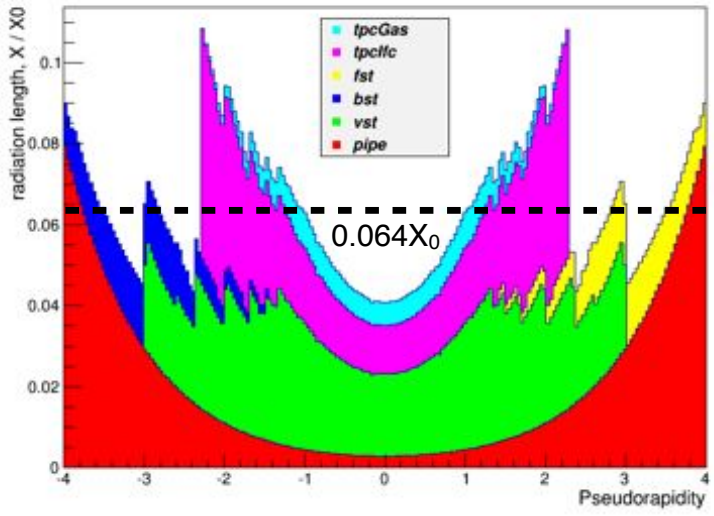


(b)

A. Kiselev (BNL)



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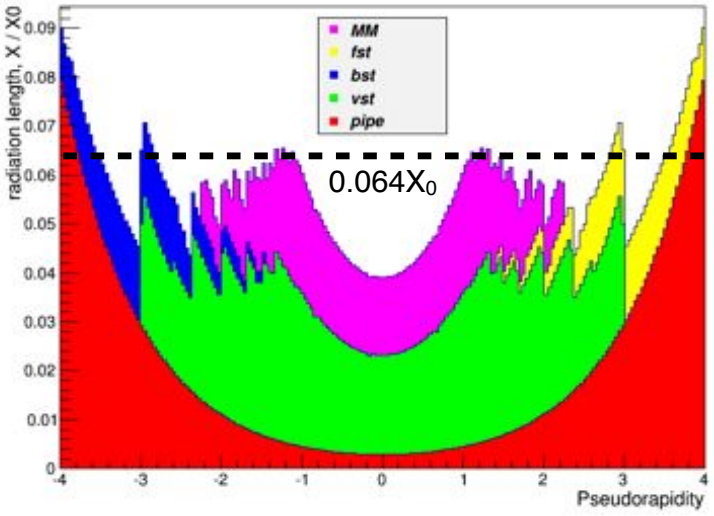


(b)

Proposal - Simulations

- Proposal
  - Systematic studies using MILOU + EICROOT for angular and momentum resolution and effect of material budget
  - Influence of the forward triple-GEM and barrel geometry
  - Effect of the magnetic field on the tracking performance of the Micromegas barrel
  - Systematic comparison with a TPC
  - Test of innovative cluster algorithms for the barrel system
  - Installation of EICROOT tools at Temple University after the experience gained in doing so at Saclay

Budget / Schedule

Budget

FY 2014: Budget items

EIC R&D Items - Sabatie / Surrow (PI, Temple University)
Items FY2014
Post Doc
Undergraduate student support
Travel - Domestic
Travel - International
Material
Equipment
Technician (TU CST) / Services (Saclay)

EIC R&D Items - Sabatie / Surrow (PI, Temple University)
Equipment / Material Items FY2014
HV unit / CAEN
Stainless steel tables
10X10 single-mask GEM foils
40X40 single-mask GEM foils
Fume exhaust system
Solid Works Design CPU
Particle Counter
Tooling setup
DAQ control PC
Monitoring system (Temperature / Pressure)
Gas leak detector
Kapton tubing material
Misc. items (Cables / Gas / Gas equipment etc.)

FY 2015: Total budget sheet and breakdown

EIC R&D Overview - Sabatie / Surrow (PI, Temple University)	FY 2015
Personnel / Travel	
Post Doc / PI	$70,460
Undergraduate support	$3,960
Total Salaries	$74,420
Fringe benefits	$15,256
Total Personnel	$89,676
Travel - Domestic	$25,000
Travel - International	$14,000
Material / Equipment	
Material	$28,902
Equipment	$50,805
Other	
Services	$79,120
Total	
Total Direct Costs	$287,503
Modified Total Direct Costs (MTDC)	$236,698
F&A: 26%	$61,542
Total Project Costs	$349,045

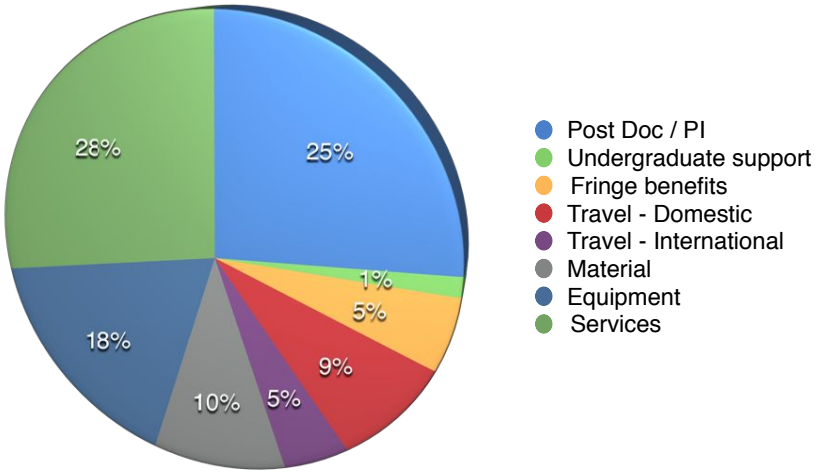
FY 2015: Equipment / Service / Material items

EIC R&D Equipment - Sabatie / Surrow (PI, Temple University)	FY 2015
Equipment Items	Amount
CCD Camera	$1,000
Linear motor stages	$27,000
Controler	$8,785
Keithley Electrometer	$7,870
Misc. Items	$1,000
Computing	$5,150
Total Equipment	$50,805

EIC R&D Services - Sabatie / Surrow (PI, Temple University)	FY 2015
Service Type	Amount
Technician (TU CST)	$21,120
MicroMegas Production / FEE development (Saclay)	$58,000
Total Service	$79,120

EIC R&D Material - Sabatie / Surrow (PI, Temple University)	FY 2015
Material Items	Amount
Frames	$1,540
2D readout foils	$1,690
Single-mask GEM foils	$5,922
HV foils	$670
FEE components	$6,080
Tooling	$13,000
Total Equipment	$28,902

Highest priority: Scientific labor (Post Doc) followed by FEE development and CCD scanner upgrade!



Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

Budget / Schedule

Schedule

EIC R&D Forward and Barrel R&D Schedule	Time in Months for FY 2015											
Items	10	11	12	1	2	3	4	5	6	7	8	9
(1) General:												
Postdoc at Temple University												
Postdoc at CEA Saclay												
(2) Forward triple-GEM R&D:												
Characterization of large single-mask GEM foils up to 50cm X 50cm												
Upgrade of optical CCD scanning setup for large GEM foils up to 50cm X 100cm												
Assembly of GEM detectors with Kapton ring spacer grids and single-mask GEM foils of 40cm X 40cm												
Cluster size studies and 55Fe gain studies with small chambers of 40cm X 40cm												
Finalize design of large dedicated EIC GEM detectors of 50cm X 100cm												
Systematic 2D readout foil tests of 40 X 40cm												
Commercialization of production of very large single-mask GEM foils to 50cm X 100cm												
(3) Barrel MicroMegas R&D:												
R&D on small radius MicroMegas prototype												
Assembly of large radius MicroMegas prototype												
Test of large radius MicroMegas prototype												
(4) FEE development												
FEE GEM readout system development using DREAM chips												
DREAM chip upgrade												
(5) Simulations												
Analytical resolution studies												
Dead material studies												
Kinematic variable resolution studies including detector effects												
Simulation setup at Temple University												

Summary

- Summary
  - Forward GEM tracking
    - Highlight: Successful commercial single-mask production of large GEM foils / Critical characterization of leakage current and optical uniformity at Temple University
    - Next: Triple-GEM configuration test with Apical spacer grids and eventual DREAM chip FEE / DAQ
  - Barrel MicroMegas tracking
    - Highlight: Successful assembly + test of small radius MM prototype with 2D readout using DREAM chip FEE / DAQ
    - Next: Assembly + test of large radius MM cylindrical shell with 2D readout using DREAM chip FEE / DAQ
  - FEE
    - Highlight: Successful test of DREAM chip DAQ ➜ Setup for triple-GEM DREAM DAQ system (Integrated readout!)
  - Simulations
    - Highlight: Installation of EICROOT on Saclay's computer grid / Dead material studies / DVCS studies
- Outlook
  - Assembly and test of larger segments ➜ Conclude 'RD 2012-03' program!
  - Plan: US / EU Ph.D. program between Temple University and Paris 6 / Paris 11 / Saclay

Backup - Apical Polyimide Material

http://www.kaneka.com/kaneka-americas/products/apical

Contact

Kaneka Texas Corporation
6161 Underwood Road
Pasadena, Texas 77507 USA
Telephone: 281-447-0755
Fax: 281-447-0757
E-mail: apical@kanekatexas.com

Click here to submit information request

Comparison of APICAL Polyimide Film and a Competitor*

Property	Unit	APICAL Polyimide 100AV	APICAL Polyimide 100NP	Competitor*	Test Method
Ultimate Tensile Strength (MD)	psi Mpa	35,000 241	44,000 303	33,500 231	ASTM D-882
Ultimate Elongation	%	95	90	72	ASTM D-882
Tensile Modulus	psi Gpa	460,000 3.2	600,000 4.1	370,000 2.5	ASTM D-2176
Density	g/cm^3	1.42	1.45	1.42	ASTM D-1505
Coefficient of Friction Kinetic	.	0.40	0.50	0.48	ASTM D-1894
Flammability	.	94 V-0	94 V-0	94 V-0	UL 94
Coefficient of Thermal Expansion (100°C to 200°C)	cm/cm/°C	3.2x10^{-5}	1.6x10^{-5} Analyzer	3.2x10^{-5}	Thermal Mechanical
Shrinkage (200° C, 2 hours)	%	0.04	0.04	0.03	IPC TM 650, 2.2.4 Method A
Dielectric Strength	V/mil	7,800	8,000	7,700	ASTM D-149
Moisture Absorption 50% RH at 23°C Immersion for 24 hours at 23°C	% %	1.3 2.9	1.3 2.1	1.8 2.8	ASTM D-570

Backup - Apical Polyimide Material

kaneka

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Kaneka Corporation of Osaka, Japan is a $5 billion* producer of chemical products including resins, pharmaceutical intermediaries, food supplements, synthetic fibers, and fine chemicals. Kaneka Corporation was established in 1949 when its main products were caustic soda, soap, cosmetics, edible oils and electric wires. Later, the company diversified into polymers, fermentation, biotechnology and electronics, and other fields. Business activities now span a broad range of markets: synthetic resins, resin products, chemicals, foodstuffs, pharmaceuticals, medical devices, electrical raw materials and synthetic fibers. Our 3,300 employees (8,400 including subsidiaries) are meeting our customer needs on all continents; Kaneka has overseas subsidiaries in the United States, Belgium, Germany, Singapore, Malaysia, Australia, China, Vietnam, India, Taiwan and South Korea.

*Consolidated Base